DOCUMENT RESUME

ED 429 968 SP 038 471

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TITLE Coming To Know: The Role of the Concept Map--Mirror, Assistant, Master?
PUB DATE 1998-00-00
NOTE 15p.
PUB TYPE Reports - General (140)
EDRS PRICE EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Cognitive Mapping; *Concept Mapping; Elementary Secondary Education; Foreign Countries; Higher Education; Learning Strategies; Memory
IDENTIFIERS *Reflective Thinking; *Self Regulation

ABSTRACT

This paper explains the process of creating and managing concept maps, using reflection as a focus for its argument. Section 1, What is a Concept Map?, highlights the background and definition of concept mapping, explains how maps signify virtual conceptual structures, looks at structural knowledge, provides an example of a concept map, and discusses associationism. Section 2, Self-Regulation, focuses on self-regulation, which makes individuals goal directed and helps in implementing intentionality. It also discusses self-confrontation, which is the external juxtaposition of self-concept, feelings, or beliefs with some external physical manifestations of those feelings and beliefs. Section 3, Off-Loading, explains that off-loading occurs because of the limited capacity of working memory registers. Section 4, The Process of Concept Mapping, looks at phases in the construction of a concept map. Section 5, Mirror, Assistant or Master?, explains that this paper provided a tentative framework for the process involved in creating and maintaining concept maps, and it discusses the implications for learning and instructional design. (Contains approximately 64 references.) (SM)

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Coming to Know: the role of the concept map - mirror, assistant, master ?

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(Euroconference language - **English**)

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Abstract - **The concept map is becoming a ubiquitous tool in education. In recent years there has been a growing interest in "diagramming" or "mapping" ideas to be learned. (e.g. Jonassen et al, 1998) The approach has been championed by study skills proponents such as Buzan (1993). Maps of concepts and relationships have been used by many researchers and practitioners to help diagnose misunderstanding , improve study methods and glimpse how learners come to know. In other areas, the representation of knowledge in formalisms such as the net greatly assisted the development of intelligent tutoring systems. (e.g. Sowa, 1983) In order to better understand the claims made for its efficacy, reference to how concepts maps have been used and defined will lead to a plausible explanation of the process of "off-loading" of concepts during learning or study. (McAleese, 1994,1998) In order to demonstrate the widespread application of supporting learners with external "learning spaces" (c.f. ISLEs/ and REALs - MacFarlane, 1993, Grabinger et al , 1995, 1998) consideration will be given in this paper to techniques that formally represent knowledge in Concept-Relationship-Concept "instances". (Fisher et al, 1990) Other techniques such as reflection journals draw on the same process but are not considered in detail here. The importance of self-regulation (Zimmerman (1990) and self-confrontation (McAleese, 1985), is highlighted in this framework. The map as a mirror or an assistant to learners is well documented (e.g. Vizcarro & Leon, 1998); the question of an external representation of thinking in the form of a map determining what can be learned as well as what might be learned, is not yet fully known.**

INTRODUCTION

> *"..... it is in these shimmering and incessant embraces that the infinite patterns, the infinite Maps of the Mind, are created, nurtured and grown. Radiant Thinking reflects your internal structure and processes. The Mind Map (Concept Map) is your external mirror of your own radiant thinking and allows you to access this vast thinking powerhouse....."*
> (Buzan, 1993)

This paper provides a new explanation of the process of creation and management of concept maps. In so doing, it extends what is known about an important self-regulatory process in study and learning – reflection. This paper uses "reflection" as a focus for its argument. Reflection is the self-regulatory process that is under the control of the learner. The processes at work are wide ranging – stretching from motivational issues and self-efficacy to the recording of what is known using a net metaphor – the concept map. The paper makes a claim that both symbolic representations of what is known (e.g. concept maps) and language based representations – e.g. the reflection journal (see Gardiner & McAleese, 1998) can be understood in terms of resolving a tension between what is known and stored as cognitive operational models and what is recorded in a map or in a journal. Central to both is self-regulation. (Zimmerman, 1990; Zimmerman & Schunk, 1989) The process of self-regulation is essentially a cybernetic process. Norbert Weiner called this "the field of control and communication theory... whether in machine or in animal..." (Weiner, 1948) ' Self-regulation involves intra-personal communication – what Gordon Pask would have called meta-communication based on conversation theory (Pask, 1984) Learning involves considerable intra-personal communication while the learner reflects IN action or reflects ON or FOR action. (see Schön (1983; 1988) and Cowan (1998). The control in Weiner's definition of cybernetics is manifest in learners making sense of sensory experiences and the matching of internal representations with external manifestations. (See Kolb, 1984) An examination of what concept maps are will lead to a broader discussion of the cognitive processes involved in their construction and maintenance.

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WHAT IS A CONCEPT MAP?

Background and Definition

There is considerable literature on concept mapping. (see for example, Bogden, 1997; DeBono, 1993; Deikhoff (1982); Gaines & Shaw, 1994); Gold, 1984; Kommers, 1992; Reader & Hammond, 1993 [ii]) A concept map is a directed acyclic n-dimensional graph consisting of a set of *m* Concept Labels {C1 ... Cn} [iii] and a non-empty set of *r* Relationships or Arcs { R1... Rn)} The representation of an idea does not determine its truth value as individuals may hold "non-truthful" understandings. The representation of these sets is in terms of a diagram. [iv] Strictly the map is a graph – however hand drawn and computer generated maps are diagrams. Different representational forms are used to make diagrams of the graphs (Jonassen, 1998). The most popular – in terms of study aids – is the Mind Map (Buzan(1993). Work in this paper uses the Node-Link-Node instance associated with Kathleen Fisher (1990) and Jo Novak (Novak & Gowin, 1984) The present author has provided some additional definitions of maps in earlier papers.(McAleese, (1987;1990;1992;1994;1998)

Maps Signify Virtual Conceptual Structures

An important issues is the virtual nature of the concept map. [v] a concept map can be n-dimensional. In other words, the "map" can exist in n-dimensional space. This is the result of two properties. First, each node itself being a sign for a more complex understanding comprising of nodes and relationships. So, in the node {CLASS} in Figure 3 (below) can be "de-compressed" (see, West & Pines, 1985) into a further map. (Figure 4). [vi] The concept label {CLASS} is an incomplete model of the understanding the author has of " an inter-institutional collaborative project that set out to produce study skills materials for undergraduate students...". The concept label {CLASS} is used as a "place holder" for this more complex understanding. Second, relationships exist between the nodes in the "sub-map" created at the {CLASS} node and concept labels elsewhere in the map – shown in Figure 3 and in other "sub-maps". Figure 5 shows an incomplete map for a node {innovation strategy} which has links to the {CLASS} map and other sub-maps. These relationships and de-compressions give rise to a recursive system. Each node may be de-compressed into one or more nodes which in turn may have relationships with any other node in any other "sub-map". This is the n-dimensional nature of concept maps. Recursive dimensionality is brought about by the "de-compression" and "compression" of concept models signified by concept labels. This gives rise to two "laws" of concept maps. First, it is likely that the level of "de-compression" is a function of working memory and this would suggest that concept models are: "**L1**: *represented using the least number of concept labels and relationships - for the current understanding*". This leads to a second law: "**L2**: *each and every concept label signifies an indeterminate number of other related concept labels*". Concept maps have to be seen in virtual space – not planar or Cartesian space. The relationships between nodes can be thought of as "deep" as opposed to "surface" linkages. The relationship of concepts - one to an other - can be understood in terms of structural knowledge.

Structural Knowledge

The nature of what might be represented has been clarified by Quillian (1968) others (e.g. Donald, 1986; Jonassen et al , 1998b). Dave Jonassen has made a plausible case that concept maps provide a measure of structural knowledge. [vii]Such knowledge ".. knowledge of the interrelationships of ideas with a knowledge domain.." (Jonassen, et al 1998b; Jonassen, et al 1993) suggests that there may be an isomorphic relationship between what is known by the learner and held as such and the external representation - the map. Jonassen, et al (1998) seem to say that the map is a dynamic construction that comes about as a result of the experience of mapping. In writing about mindtools, Jonassen et al suggest "....mindtools represent a constructivist use of technology. Constructivism is concerned with e the process of how we construct knowledge.."(Jonassen, et al, 1998) The assumption here is that the maps comes about as a result of engaging in or constructing understandings. This is the "constructionist" view. However, in an other paper, the same author claims "..concept maps .. are the spatial representations of concepts and their interrelationships that are intended to represent the knowledge structures that humans store in their minds..."(Jonassen et al 1993; Jonassen et al, 1998) This is the "representational" view. In Jonassen's writings – he allows the maps to be BOTH representational and constructive. This tension is important in understanding what maps do and how they facilitate learning.

The current author would take a much more constructivist view – given the dynamic process of mapping. Concept maps are not snap-shots of what is known - rather they allow off-loading of thinking and show the result of engaging in knowledge construction. As structural knowledge, concept maps are not isomorphic of what is known. They can not therefore be used – as such – to evaluate what learners know – rather they allow learners an opportunity to engage in the process of learning. The distinction is made even more forcibly by Jonassen & Marra (1994) in a response to the McAleese (1994) paper. Jonassen & Marra suggest that maps can not ".. adequately reflect what is really in the mind .." as knowledge is "... dynamic .. not static" (Jonassen et al, 1998 citing Jonassen & Marra, 1994). They claim that concept maps are (therefore) dynamic and process

oriented. They are not snap-shots or representations of pre-existing structural knowledge.

An Example of a Concept Map

An example of a map can be seen in Figure 1 which was drawn by a student using a concept Mapping program – Inspiration – as a study aid. [viii] This map comprises 50 nodes; with 49 relationships - 19 of which are labelled. [ix] At first sight, the map looks complex and confusing. However, it was produced by an individual student – who is unique – as a personal study aid. It is NOT a definitive representation of what is known about "brewing in the United Kingdom". It is also important to note that the map was created over a period of time. [x] The learner was engaging in a process of reflection IN action, reflection ON action – with regard to a chosen topic. [xi] The map is an external mirror of the student's "...radiant thinking...."(Buzan, 1993). Jonassen and others (Jonassen, Kommers and Mayes, (1990) ; Kommers, (1992)) have described the concept map as an instance of a "mindtool". [xii] As such, a concept map functions as an aid – helping the learner interpret and organise personal knowledge. A mindtool allows the learner to interact with their own understandings through some external manifestation. The simplest manifestation is to allow what is known to be represented in terms of nodes and relationships/ arcs. (McAleese, 1987) The simple cognitive process that generates the sets of nodes and relationships is associationism.

Associationism

The idea that one concept generates links with another concept and that the building blocks for thinking are related as chains or cascades can be traced to Aristotle. In a well cited reference to James Mill (1829) the cascade of thinking is well exemplified. "When I see a horse that is a sensation. Immediately I think of his master, that is an idea. The idea of the master makes me think of his office – he is minister of state.. the idea of a minister of state makes me think of public affairs...." The cascade of associations is the triggering of Concepts that one Node creates in the mind of the learner. The learner in making sense of an idea uses a conceptual model comprising linked or associated nodes to store understandings. Associationism is also exemplified in hypertext and hypermedia. The original idea of hypertext (Bush, 1948; Nelson, 1988) used the associative power of the mind to build complex webs of inter-related ideas. While the term hyper-media is now used widely to imply any multi-media presentation where the user can exercise choice on what is read/ seen/ heard – the essence of hypertext/media is that of associationism. Individuals browsing through hypermedia documents or chunks are using associations to determine what node is visited next. (see McAleese, 1989 for a discussion of browsing in hypertext) This process is a self-regulated process. The question of self-regulation needs to be examined in detail.

SELF-REGULATION

Self-regulation forces and keeps the learning process "ticking over". (Schunk, 1989) Self-regulation is that control mechanism that makes individuals goal directed and assists in implementing intentionality. (Zimmerman & Schunk, 1989) Without an ability to plan for action and know what tasks need to be carried out and the ability to assess how successful action has been to achieve goals, an individual would not exhibit what we judge to be rational behaviour or achieve academic success. Organisms can either exercise this control themselves or have it imposed on them by some other agent or system. In practice individuals are effected by control mechanisms that are both external and internal. There is a resultant balance sought and achieved between these competing forces. This balance is referred to as locus of control (LoC). Rotter (1966) defines LoC as ".. the manner in which a person feels he himself (internal control) or factors in the situation (external control) determine his behaviour..." That is, the initiative to act or respond is determined by factors which may or may not be within the control of the learner. LoC is a way of describing the balance between competing forces which act to control systems. If the learner does not believe that events are brought about as a consequence of their actions, the LoC is said to be with the system. [xiii] LoC seems to have two theoretical perspectives – according to Rossouw & Parsons (1996). The first, a social learning theory perspective – in which the learner (students) are primarily concerned with "...the identification of individual... tendencies in (the) perception of control.." The second perspective, an attribution theory perspective, ".. focuses on the identification of situation specific variables...". Studies of LoC suggest a complex tension within students which may be brought under control if students have the ability to reflect on their state and disposition. (Craig, et al, 1984) In addition to planning and evaluation, learners need an approach to external tasks and situations that Donald Schön has called Reflection IN Action and Reflection ON Action (Schön, 1983,1988) The concept map establishes self-regulatory effects in learners. The LoC shifts between the conscious self-regulatory learner and the external locus – the concept map (see below). A component of self-regulation is self-confrontation.

Self-Confrontation

Self-confrontation is a process closely associated with metacognition (Osman & Hannifin, 1992) and reflection and is associated with the cognitive-constructivist view of self-regulation. Self-confrontation is the external juxtaposition of self-concept, feelings or beliefs with some

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external physical manifestation of those feelings, beliefs etc. The best known situation is where a learner is able to see or hear a recording of the post-performance of some skill. For example, in sport, it is common in training to use video recordings for feedback in swimming, golf and tennis. In essence, a video record is used to confront or show an individual how they performed. It is therefore a **performance aid**. Within an educational and psychological context, video has been used for both training and counselling. Probably the most prolific source of evidence of the process at work come from the use of video (CCTV – closed circuit television as it was called) to shape or modify novice teachers in what was called "microteaching". (Allen & Ryan, 1969) Similarly, self-confrontation is the process at work while students use performance aids such as concept maps and learning logs. Experience with such performance aids did suggest that the process of self-confrontation caused "cognitive dissonance" (Festinger, 1957). This felt state of cognitive uncertainty or puzzlement is important in concept mapping. The "dissonance" between the external and the internal representations has to be resolved and it is in this resolution that new concept labels are created and relationships made and edited. This process is complex and uses a lot of working memory capacity. In fact working memory is inadequate to handle such disambiguation. There is ample evidence from different sources that working memory is a constraint in disambiguation (Stenning, et al 1995). The brain has to supplement its operation or working area and this is achieved through off-loading.

OFF-LOADING

If one accepts the common view that there are two types of memory – short term and long term (e.g. James, 1890; Baddeley, 1992), then it is reasonable to suppose that the capacity of the short term memory registers is a limiting factor on the immediate processing of information. In an earlier paper, the present author presented an explanation of the process of concept mapping in terms of a learning arena. This arena is the concept map. At the heart of the argument was the observation that the limited capacity of working memory registers lead to what Sweller called "off-loading" (Sewller & Chaldler, 1991). McAleese saw the visualisation that the concept map afforded as providing an adjunct to the working memory. The concept map was a performance aid – a learning arena where the learner could " ..interpret and organise their personal knowledge..."(Jonassen, et al 1998). Given the way an individual processes a concept map, or compares what is known to what is recorded in a map (see below), the limited capacity of working memory has to be taken into account. Different views exist on the exact capacity of STM. It matters little if there are 7 "registers" (Miller, 1956) or 3 "registers" (see Broadbent, 1975). An extension of this capacity through off-loading (Sweller, & Chaldler, 1991) is likely to provide more complex processing and enable an individual to more effectively disambiguate complex ideas (see, McAleese, 1994; 1998) Information processing depends on the ability of some function of the brain to make comparisons or top hold "in view" a complex idea or model while it is operated on. Individual concepts act as chunks (see Miller, 1956). In Figure 1, the student is chunking complex ideas with long concept labels. For example { Rejected by the Lords, Liberal Party fell from power}. This chunk - in terms of understandings – is associated with {1st laws limiting alcohol proposed}. In order for an individual to hold significant areas of this map in short term memory, two effects must occur. First the individual uses a short hand label for complex ideas – for example { Rejected by the Lords, Liberal Party fell from power}. This chunk is a sign for a more detailed cognitive model. Second, the map is used by the individual to provide a display or representation arena where many such chunks can be operated on (see McAleese, 1994)

THE PROCESS OF CONCEPT MAPPING

There have been very few attempts to explain the process of constructing and maintaining a concept map. [xiv] The creation and modification to a concept map is clearly a process that involves a number of discrete but inter-dependent steps. (see Figure 1) There is a sub-process of initial node and/ or relationship creation. This is followed by a number of sub-process including the modification of the initial map created with further additions and deletions. In order to clarify the process the author created a series of maps based on reading a textbook. [xv] Figures 2 and 3 show two maps. [xvi] Figure 2 is a snapshot of the initial map. It consists of 33 nodes (concept labels) and 28 directed arcs or Relationships. There are two main clusters – one comprising 6 nodes; the other comprising 26 nodes and a singleton {Cybernetics}. The main cluster is a composite of two sub-clusters – with {Perception} related to {Mental Models} The starting node { Conceptual Structures} is differentiated from the others with a different iconic representation – an ellipse as opposed to rectangle. .Figure 3 shows the state of the map after the author had added new nodes; made additional Relationships (labelled and unlabelled) and adjusted the nodes to show better the relative semantic similarities of the concepts and to disambiguate nodes and relationships – in terms of spatial layout. Figure 3 has 50 nodes; with 51 relationships (directed arcs) . Of these relationships 13 are labelled. The map comprises two clusters of nodes – the smaller (centred around {Cybernetics} comprises of 9 nodes – all added after the initial creation (Figure 2). There are at least three different mapping situations that arise. The different situations comprise:

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- The recall of previously learned and known ideas – the individual thinking "What do I know about {x}? Typically during revision or as a part of learning new material.
- The recording of new ideas as a result of some learning situation – e.g. reading a book , listening in a lecture - the individual making notes in a Concept Map as a study aid;
- An individual "thinking about" some already known idea or ideas in response to some event or situation.

Phases in the Construction of a Concept Map

The process of map creation starts with an individual intending to make sense of something that is knowable. The process of map creation and maintenance based on this example falls into the following ten phases:

1. Creation of "seed" node; a map must start with one "concept". The person constructing the map – may have a series of ideas but the first is critical. It - along with any other first order concepts trigger the subsequent cascade.
2. Addition of associated nodes using a "rapid fire" technique of recording the remaining first order of associated nodes; in addition there may be the addition of relationships.
3. The creation of new clusters of nodes with additional "seed" nodes; nodes and relationships may be typed. [xxii] Certain relationships will require a particular type of node – for example {fermentation} {causes} {carbon dioxide}. The {causes} relationship will trigger a particular type of related concept.
4. The addition of singleton nodes; such node may later be included in clusters when they have relationships added.
5. The creation of relationships between existing clusters or singleton nodes;
6. The labelling and typing of relationships;
7. The deletion of nodes and/ or relationships;
8. The editing of concept labels, types and relationship labels;
9. The editing of concept icons; this may involve a global typing – for example – all the nodes that refer to authors may be a particular icon type imposed.
10. The movement of nodes or clusters of nodes to accommodate tacit or explicit semantic rules; this may involve using semantic similarity to cluster node and to place apart nodes of different types.

These stages form a multiple-recursive progression. Step 1 is not repeated. The time taken for this process was about 30 minutes. What cognitive explanation can there be for these events?. If one starts with a static description of the dynamic process the following phases can be suggested. [xviii] In general individuals tend to create nodes first; then make relationships; followed by labelling of relationships and typing of nodes.

(a) The Concept Map - comprising *n* {Concept Labels} and *m* [Relationships/ Arcs] displayed on the computer monitor [xix] gives rise to a sensory image (S). [xx] The image is a representation of the Concept Map (M). The image is created through sensory input channels – e.g. the eyes and activates specialised areas of the visual cortex. [xxi xxii xxiii]

(b) An Associative Comparitor [xxiv] finds one or more Percepts (P_1 to P_n) from a cognitive store that match some or all of S. [xxv]

(c) An Assembler combines the retrieved Percepts to form a Working Model or Cognitive Graph that approximates to S. For each Percept in the Working Model – there is an isomorphic Concept Label C_1 to C_n. The creation of the Working Model is a transient stage. The Cognitive Graph is the stored understanding of any one idea.

(d) If such a Working Model can be constructed using the Percepts, the Map (M) is explained by the Working Model and by definition makes sense to the individual. This state leaves the individual "happy" or "content" that they can make sense of the idea using the map M.

(e) If the Working Model is in any way deficient or can not adequately explain the Map (M), the individual either shifts their attention to an other area of the Map – and steps a to d re-occur, or the individual retrieves an existing Cognitive Model of one or more Concepts. These Models lead to the creation of a new Concept label or relationship through interaction with the computer application.

(f) New Concept labels or relationships are created. This step is in response to the ambiguity created when the Working Model is not adequate to explain the sensory image (S). This step creates new nodes and/ or relationships.

MIRROR, ASSISTANT OR MASTER ??

A plausible but still tentative framework has been provided for the process involved in the creation and maintenance of concept maps. What are the implications for learning and instructional design? A tension has been implicit in the framework suggested. On one hand the map is an assistant providing a extension to cognitive capacity. It is in part a mirror – showing the learner what it is that they know. Allowing the individual to be aware or the relations within and between cognitive models of concepts. As a mirror the map would only reflect – externally – what

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is and how it is known. It seems most unlikely that a map is such a static device. No one who has used a concept map would doubt that their understanding of what ever it was they mapped remained totally unchanged. There is some interaction between the external representation and the internal understanding. The experience of the map leads to reflection – this reflection is generalised and tested against subsequent experiences (c.f. Kolb, 1984) With off-loading the learner is able to process complex ideas in a that would not be possible with out its functionality. The assistant role is very important yet it brings with it an external Locus of Control. It may be that representation in terms of a formalism determines what can be known. A number of aspects to this claim should be noted. First, the metaphor itself determines the inter-relatedness of concepts. Second, the learner is predisposed to make relationships between unconnected concepts.

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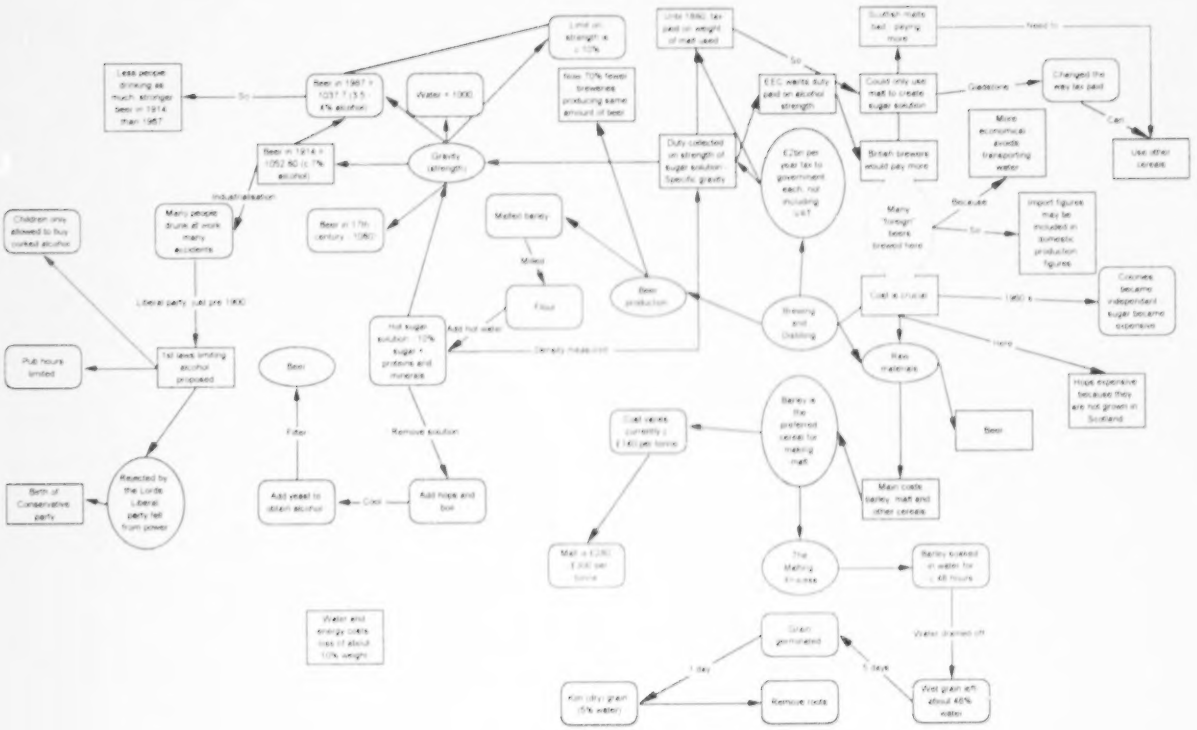
Less people drinking as much, stronger beer in 1914 than 1967
So
Beer in 1967 = 1037.7 (3.5 - 4% alcohol)
Limit on strength = < 10%
Water = 1000
Now 70% fewer breweries producing same amount of beer
Beer in 1914 = 1052.60 (5.7% alcohol)
Gravity (strength)
Industrialisation
Children only allowed to buy corked alcohol
Many people drunk at work many accidents
Beer in 17th century - 1060
Liberal party - 1st pre 1900
Pub hours limited
1st laws limiting alcohol proposed
Rejected by the Lords. Liberal party fell from power
Birth of Conservative party
Beer
Filter
Add yeast to obtain alcohol
Cool
Add hops and boil
Remove solution
Hot sugar solution - 10% sugar + proteins and minerals
Add hot water
Gravity measured
Malted barley
Mixed
Filter
Beer production
Water and energy costs rise of about 10% weight
Duty collected on strength of sugar solution - Specific gravity
Since 1880, tax paid on weight of malt used
So
EEC wants duty paid on alcohol strength
£2bn per year tax to government each, not including VAT
Brewing and Distilling
Could only use malt to create sugar solution
Gladstone
British brewers would pay more
Scottish malts last - paying more
Changed the way tax paid
Can
Use other cereals
Mixes economical avoids transporting water
Because
Many "foreign" beers brewed here
So
Import figures may be included in domestic production figures
Cool
Coal x crucial
1880 s
Colonies became independent sugar became expensive
Here
Raw materials
Hops expensive because they are not grown in Scotland
Beer
Barley is the preferred cereal for making malt
Main costs barley, malt and other cereals
Coal varies currently £140 per tonne
Malt = £280 - £300 per tonne
The Malting Process
Barley soaked in water for c. 48 hours
Water drained off
5 days
Wet grain left about 45% water
Grain germinated
1 day
Remove roots
Kiln dry grain (5% water)

Figure 1 Concept Map Drawn By University Student as Study Aid

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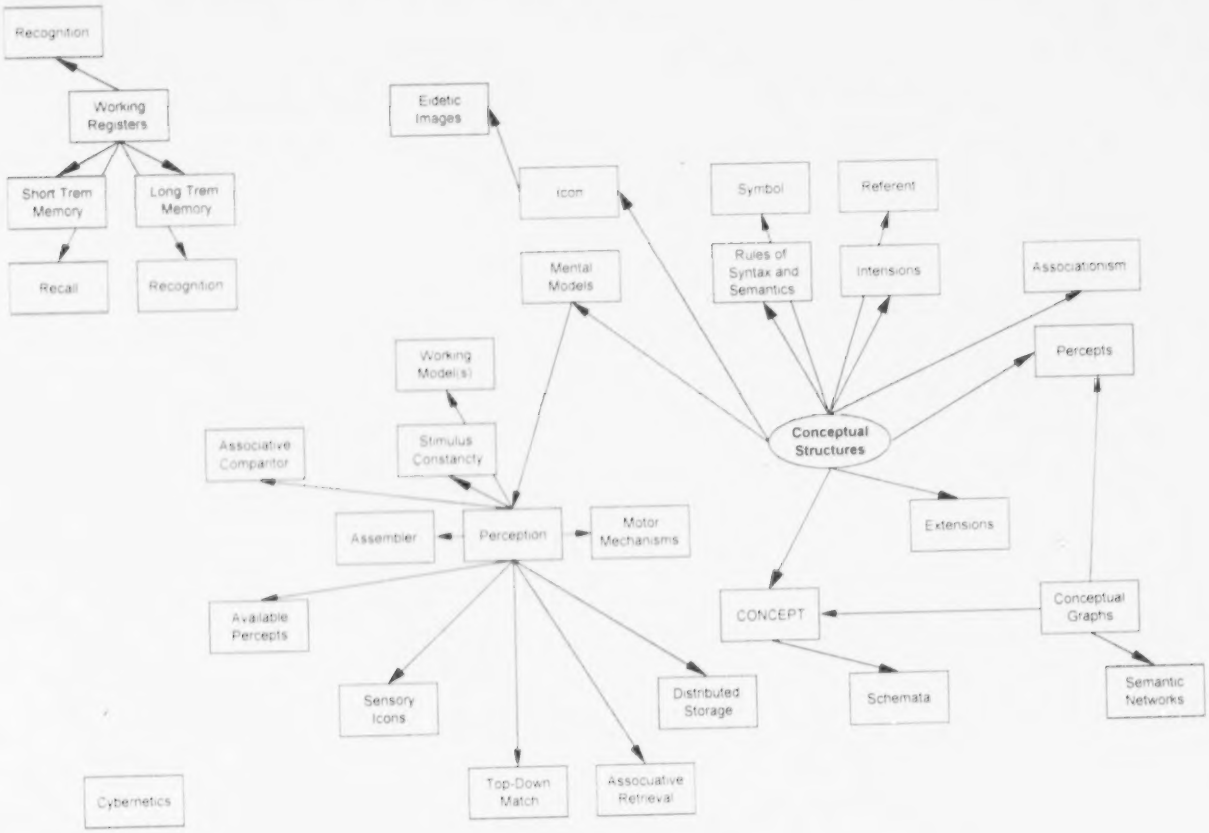

Figure 2 "Initial" Concept Map Created by Author – immediately after reading Sowa (1983)

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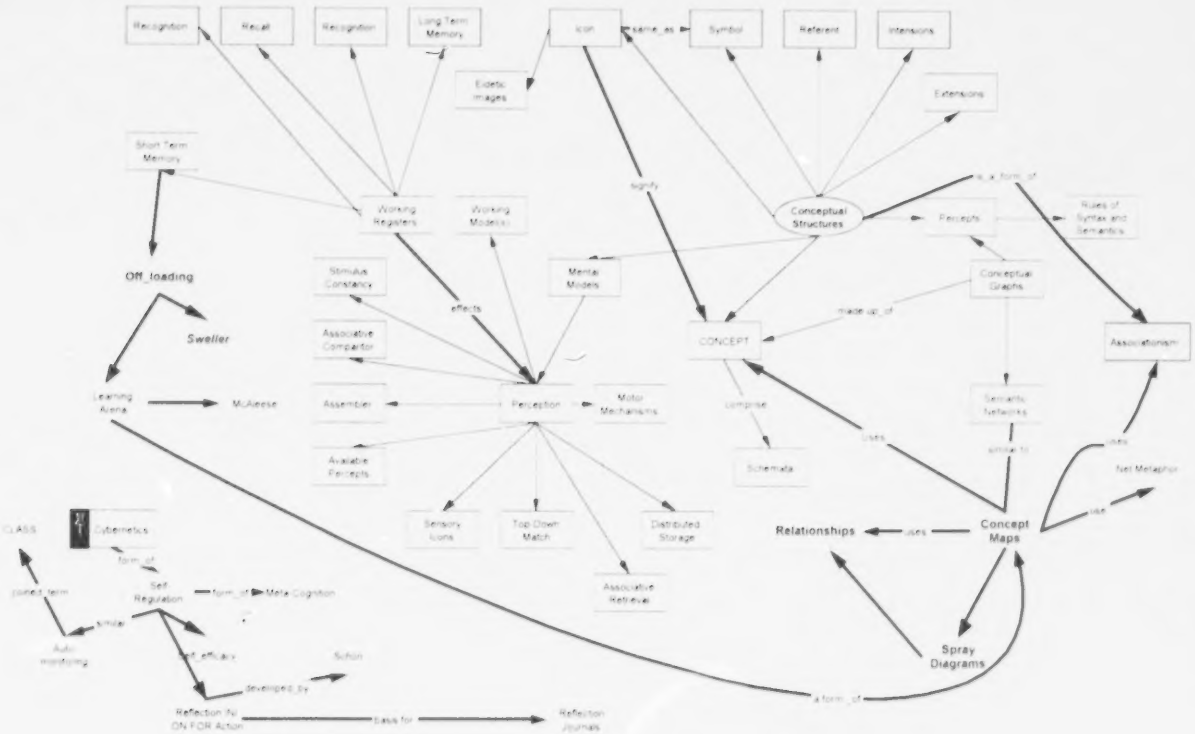

Figure 3 Concept Map Created by the Author – after adding nodes, relationships etc

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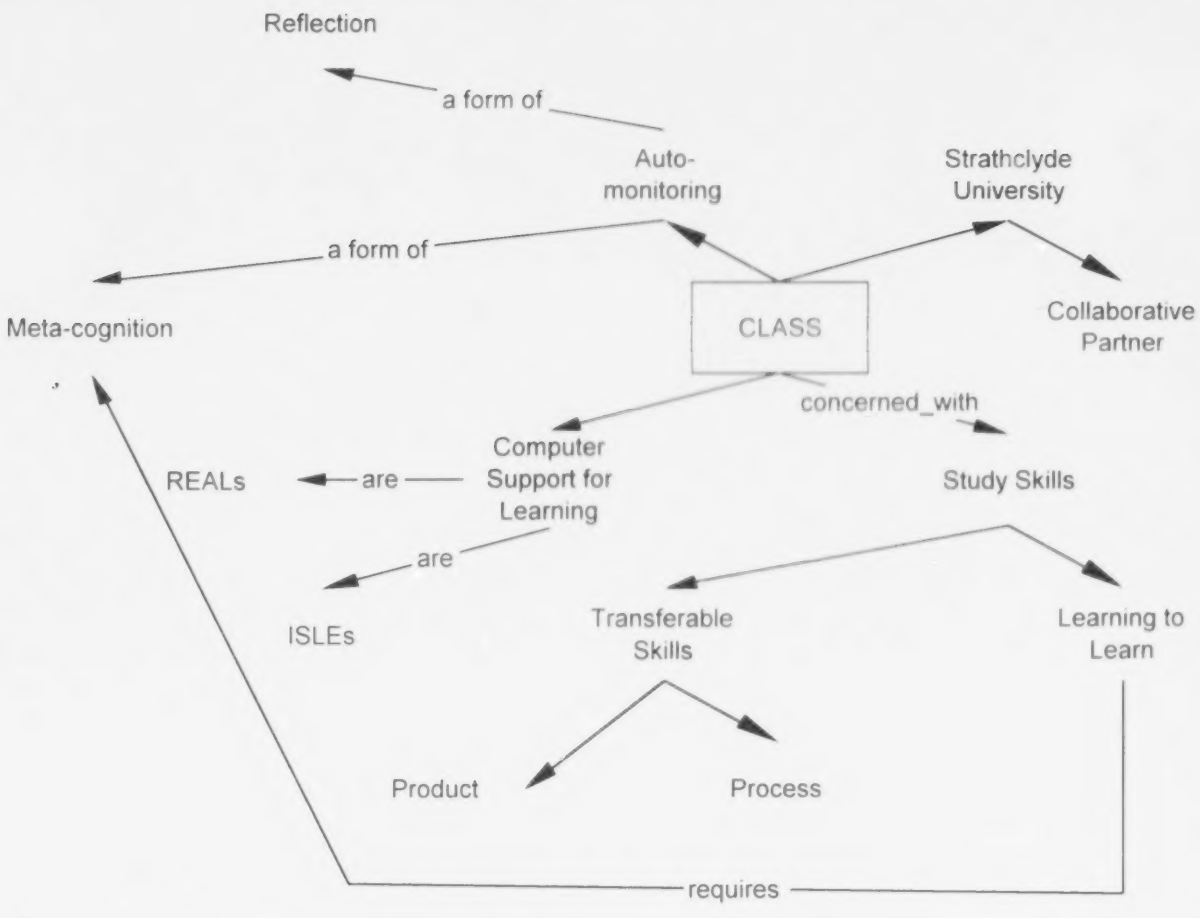

Figure 4: "Daughter" map for {CLASS}

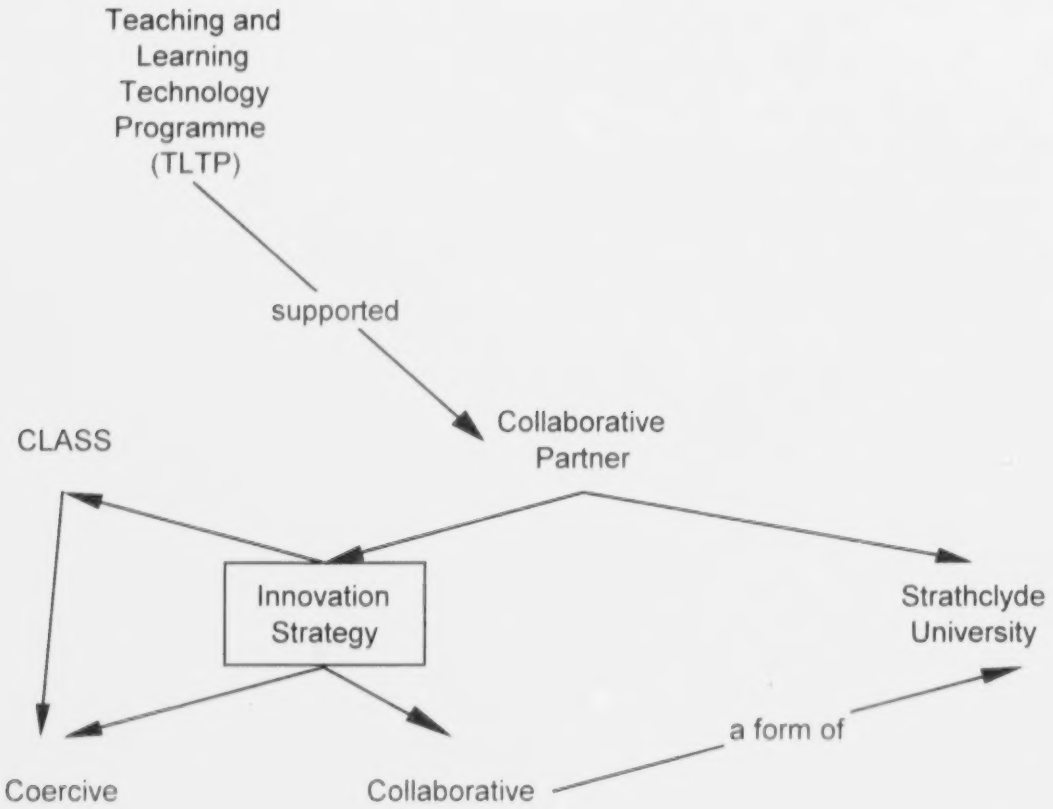

Figure 5. "Daughter" map for {Innovation Strategy}

ENDNOTES

[i] It is tempting to use the micro analysis of neural nets as conceived in cybernetics to provide an isomorphic explanation of concept maps. The temptation should be resisted. While there is ample evidence of message passing and activation ripples in neural activity – similar to associationism in concept mapping – there is no claim made in this paper that concept maps are isomorphic with neural activity. The principal reason is the granularity of the entities. Concept maps involve Concepts and Percepts – which are magnitudes of complexity greater than the activation of one neural center and the co-activation of adjacent nodes.

[ii] Each of these citations uses different assumptions about the nature of concept maps and the name used – e.g. Mind Maps (Buzan)

[iii] The convention of placing within curly brackets { } the concept label or the relationship will be followed. The brackets represents a non-empty set – with minimally one member – e.g. {c a t} or {causes}

[iv] The question of what exists "at" a node or by a relationship is complex. In practice the sign represented signifies a cognitive model. So, {c a t } signifies all the known characteristics and attributes for the family pet; similarly {causes} signifies a state of effect of one agent on another. {causes} is a sign or label for a model of "causality" according to an individual. Thus {cat} {causes} {Chaos} is a meaningful belief/ understanding by an individual – represented in terms of two nodes and one directed relationship. This means that nodes and relationships comprise signs that signify concept models.

[v] "Virtual" signifies a symbolic non-real space. Concepts do not exist per se in the human brain.. We understand their operation and significance in terms of their existence as entities. Such entities can be represented in a symbolic system - a "virtual space".

[vi] "De-compression" is an important idea. Its definition is slightly counter intuitive. When a concept (concept label) is de-compressed it is expanded to show all other concepts/ concept labels that it comprises. In some software that supports mapping this is achieved by creating a "family" of nodes – each node having a parent (compressed) form and n-generations of children (de-compressed) nodes. However, in available commercial software (e.g. Inspiration), links are nor possible from leaf nodes of "children-maps" to leaf nodes in "parent-maps". In reality, such relationships exist.

[vii] The term "structural knowledge" is an extension to the classification "procedural" and "declarative".

[viii] Inspiration is a commercial application that is designed to be used in a number of brain-storming and outlining situations. [Inspiration Software URL: www.inspiration.com/techsupport.html]

[ix] This map is the result of the following scenario.

a. Students were taught to produce patterned notes in the form of concept maps using Inspiration.
b. A class of students were given a lecture on the Brewing Industry in the UK as part of a study Skills course – where they had to demonstrate their competence in analysing data and writing reports.
c. The students were asked to make notes during the lecture and to submit a patterned note-style concept map using Inspiration after the lecture. This map is a map submitted by one student.

[x] The temporal nature of concept maps is not recorded in most literature. The temptation is to see a map as a fixed or static product. Rather it is a snap shot of a process.

[xi] The terms "reflection IN" and reflection ON" - action, were coined by Donald Schön. When individual reflect ON action they consider events that have occurred; when they reflect IN action, they consider events as they occur. (Schön, 1983;1988)

[xii] The present author has developed a concept mapping program that allows for learners to represent formal semantic structures such as an "argument". In this specialised or constrained form of map, the nodes are typed allowing certain pre-defined categories of concepts to be represented – for example: Claim, Warrant, Backing, Evidence etc. This work is based on formal communication structures provided by Kuhn (1992); and Streitz & Hanneman (1990). It is influenced by Toulmin (1964). See also Ranney, et al (1992) for an approach to mapping based on Evidence and Theory.

[xiii] Characteristics of "Locus of Control" will be : learners can anticipate difficulties and take action to avoid them; learners believe that their plans will lead to outcomes they can envisage; are that mistakes are controllable. (See Scale(s) used to measure LoC, such as Craig et al (1984).

[xiv] See Batley, S. & McAleese, R (1986) Concept Maps: A Bibliography University Teaching Centre, Aberdeen University (Mimeo) ; & Lanzing, J W A (1997) Concept Mapping Bibliography [URL: www.to.utwente.nl/user/ism/lanzing/cm_bibli.htm]

[xv] The techniques used was as follows:

i. A book was selected and read for about two hours. The book (Sowa, J F (1983)

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ii. Conceptual Structures: information processing in mind and machine, Addison Wesley, was chosen as it was related to the topic of this paper and the author knew he wanted to read it or sections of it again for that purpose

iii. After reading the book for two hours, the author used the computer application Inspiration on a PC to make the concept maps. The author is familiar with the application and used the following technique:

iv. Using a "rapid fire" facility, as many nodes as possible were created.

v. The map (Inspiration file) was saved from time to time and snap shot screen snaps were created in BMP format.

vi. The concept labels were spell checked and a number of alterations made. No attempt was made during "rapid fire" node addition to be precise in spelling of the labels.

[xxi] The maps in Figures 2 and 3 are snapshots. The process is dynamic. However Figure 2 is an initial stage where the majority of nodes associated with the source text are "dumped". The stage of Figure 2 is an end point – used for this paper. The can be no final end point as logical the author could re-visit the Figure 2 map after some time and made additional alterations.

[xxii] A typed node is a node of a particular category of concept. For example "counter-example". Such a node may have a unique icon signifying its type.

[xxiii] This explanation draws on the work of Sowa (1983); Sweller & Chaldler (1991) and McAleese (1994).

[xxiv] There is no reason to believe that paper and pencil concept maps - e.g. Buzan-style are significantly different. The creation of hand drawn maps may cause some slowing down of the cognitive processing but otherwise the situations are comparable.

[xxv] Clearly there are a series of sensory images but for the sake of clarity. It can be assumed that there are minimal differences between adjacent images S_i and S_{i+1}. The subject will be aware of the incremental creation of labels as the letters appear on the screen – however, for simplicity we will assume complete labels and complete nodes and relationships. Rainer et al (1998) suggest that focal attention has a significant effect on the ability of short term memory to make use of information. In deed they suggest - in animal studies - that ".. working memory directs attention..". The significance of this for concept mapping is still not clear.

[xxvi] Different areas of the visual cortex must be activated. There is no direct evidence using Concept Maps with regard to the exact areas. However, it is likely to be the pre-frontal cortex. (see, Rainer et al, 1998)

[xxvii] The individual will focus on selective areas of the Map. For example – in Figure 2, the author might "look at" {Short Term Memory}. The resultant creation of the new node {Off-loading} is a result of steps a to e in the text above. In other words the individual will selectively examine the Map – scanning the nodes and relationships in a systematic fashion. Eye saccades will determine the extent and details of that the learner perceives and processes. (see, for example, Hoffman, J E & Subramaniam, B, 1995)

[xxviii] The sensory image is created in a visual buffer. The capacity of this buffer is limited although manipulation of images is possible. Such images comprise Percepts and Concepts which give rise to the image. It is the limitation in size of the visual buffer that gives rise to the off-loading of thinking (see, Sweller & Chaldler, 1991) in to what the present author has called the learning arena (McAleese, 1994).

[xxix] See Sowa (1983) p70.

[xxx] The "working area" is taken to be the Working Memory. It is within these registers that the operations on the elements of the map and the existing models occur. There is evidence that the capacity of visual working memory is enhanced by "chunking" or integration of individual elements. (see, Luck, & Vogel, 1997)